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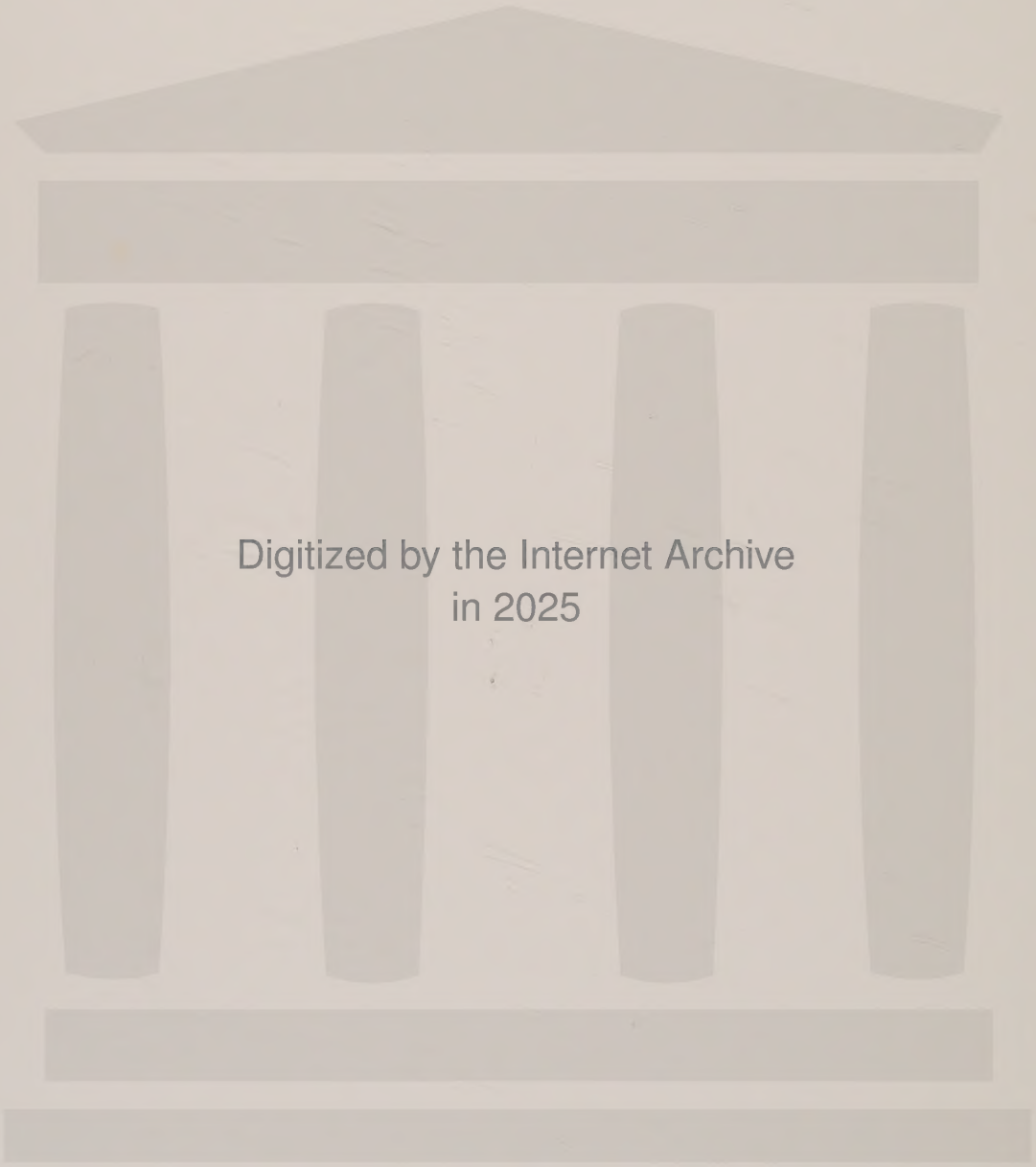
Potential Fisheries Capability of the Ord in the Short, Medium and Long Terms

BY

DR N. MORRISSY

PERTH
WESTERN AUSTRALIA

1983



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Department of Fisheries and Wildlife

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PERTH

REPORT

No. 59

POTENTIAL FISHERIES CAPABILITY OF THE ORD IN THE SHORT, MEDIUM AND LONG TERMS

BY

N. MORRISSY

1983

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POTENTIAL FISHERIES CAPABILITY OF THE ORD IN THE SHORT, MEDIUM AND LONG TERM

N. MORRISSY

I INTRODUCTION

This report examines the history, future and problems of various methods for development and exploitation of the fisheries resources of the Ord.

The primary resource is the array of native fish and crustacean species, with the possible introduction of other desirable or noxious species being a subject for consideration.

Water resources, supporting these species, are the remaining natural Ord River downstream from the Diversion Dam at Kununurra, the stillwaters of Lake Kununurra and Lake Argyle, and, for aquaculture, the controlled distribution of water supply over the flat land of the irrigation system (Fig. 1). Another recognized resource is the climatic suitability of the Ord for aquaculture production.

Conventional methods of exploitation are commercial (professional) and amateur (sport) catch fisheries. A third important, and as yet unrealized, method is aquaculture; the latter includes farming of food and ornamental (aquarium) species and the provision of tourist attractions in the form of aquariums, and associated displays, and fish-out ponds.

II SPECIES

(a) Barramundi (*Lates calcarifer*)

(i) Importance

No other northern Australian freshwater fish species offers the combination of the attainment of a large size, the gourmet eating quality and the sporting (game fish) image of barramundi. As a consequence, barramundi are renowned throughout Australia, they are a premier fishing attraction for tourists in the north and feature prominently in the south as fare in restaurants.

(ii) Biology

Barramundi is a widespread Indo-Pacific (tropical) species ranging from India to Queensland, the Northern Territory and Western Australia - down to the Ashburton River near Onslow.

The most important aspect of their biology is a particular type of life-cycle involving migration between sea and fresh waters (catadromy) (Fig. 2). Barramundi are found in tropical freshwater rivers (ranging far upstream in extensive river systems such as the Ord before damming and the Fitzroy River), in the tidal, or estuarine, reaches of rivers, and in coastal marine waters adjacent to rivers. However spawning, and egg and larval development only occur in the last habitat at high salinity during the first half of the monsoon season (October-January).

No barramundi spawn in freshwater and all maturing fish approaching first spawning at 3-4 years of age in freshwater must migrate downstream to seawater to spawn. Such large fish, once spawned, remain in the tidal and lower reaches of the rivers. O+ year old fish from recent spawning repopulate the upstream freshwater reaches of rivers during the later part of the wet season until river flows cease. Some further upstream movement by these fish occurs during the next wet season.

The consequence of this catadromous life-cycle is that any natural or man-erected barrier (such as a dam wall) prevents natural repopulation of rivers. Barramundi are not found in water storages on rivers across northern Australia.

The ability of barramundi to surmount river barriers, perhaps with assistance, and their motivation for upstream migration will be considered under III, Fish Passes. Besides Fish Passes, other possible solutions to the "barramundi problem" are stocking dams with young barramundi bred and reared in a hatchery, see V,(b), and introduction to Australia of a barramundi look-alike, its African congener, the Nile perch (*Lates niloticus*) which breeds in freshwater, see II,(e).

There is no other Australian fish species which could provide an equivalent substitute for barramundi in northern water storages. However, in the case of Lake Argyle, large stocks of a native species have developed there naturally, see II,(c), Catfish.

A further feature of the life-cycle associated with breeding is the maturation of barramundi at 4 years of age as a male stock and sex change in part of this stock at a later age (6-8 years) to provide females (protandry). Barramundi are particularly vulnerable to overfishing of the limited stock of large, i.e. highly prized, females which poses especial problems for fisheries management, see (iii), Commercial Fishing. Protandry, i.e. sex change from male to female, occurs in Australian and New Guinea stocks of barramundi but has not been

described in South-east Asian stocks. Hatchery breeding of barramundi in northern Australia, using methods successfully developed in Asia, may be more difficult because of this sexual characteristic, see V,(b), Aquaculture.

Barramundi appear to be free-ranging in the muddy tidal waters of estuaries and mangrove tidal creeks. However, in the clearer water of large inland river pools, during the dry season, the preferred habitat appears to be submerged trees, snags or weed-beds, i.e. cover close to banks, providing the base for a territory for solitary fish. This behaviour has an important bearing on the likely success of stocking large areas of clear open water, such as Lake Argyle, with barramundi, see V,(b).

(iii) Commercial fishing

Netting of barramundi by professionals is only permitted in the tidal reaches of the Ord, below Carlton Crossing (Figs 1 and 2). Only amateur fishing by rod and line, or line, is permitted in freshwater. With a minimum legal mesh size of 16.5 cm, commercial fishing exploits the mature stock of males and, particularly, large females. Since sport fishing in freshwater, relies on recruitment from this spawning stock, commercial overfishing can reduce angling success.

The magnitude of the annual catch of barramundi in Western Australia is small relative to that of Queensland, the N.T. and New Guinea. (Q, about 1000 tonnes; N.T. 400-1000 t; P.N.G. 200-400 t; W.A. 18-37 t). Australian Bureau of Statistics catch records,supplied by fishermen as a condition of their licence, show that most of the W.A. catch centres around the estuaries of the two major Kimberley River systems, the Ord and the Fitzroy. The abundance of stocks within Western Australia, and by comparison with other States, is directly correlated with the extent of large meandering river systems, associated billabongs and coastal swamps and creeks for juvenile production. Continuance of river flows during the winter season also has been described as a factor associated with high production of juveniles in freshwater. Such flows are not characteristic of northwest rivers except for some rivers flowing from the Mitchell Plateau (of high gradient and unsuitable habitat for barramundi) and with the notable recent exception of the Ord River below the continual discharge from Lake Argyle.

Decline in stocks of barramundi on the east coast of Queensland has been attributed to overfishing, dam construction, and pollution from sugar mill effluent. Most of the Queensland catch comes from

Gulf of Carpentaria stocks. The N.T. supports a large fishery but analysis of catch and effort data has shown a pronounced decline in catch rate, and particularly in the ratio of females to males, in recent years (Grey and Griffin 1979). Although barramundi females are highly fecund, recruitment failure is feared since examples are known to have occurred in stocks in other countries (Hill and Grey 1979). For this reason too, there is also considerable concern for the amateur fishery in freshwater since this fishery has been shown by angler catch and opinion surveys to make a very important contribution to the expanding tourist trade of the N.T. (In 1978, the angler catch was over 100 tonnes which was approximately one third of the commercial catch from the same area). Since professional overfishing could ultimately cause failure of both the commercial and amateur fisheries, N.T. fisheries administrators have contemplated giving preference to the amateur fishery as justifiable economically in the long term.

The regulatory measure introduced by the N.T. in 1977 of a closed season from November to January, inclusive (spawning season), and extended to include October in 1979, has been of some concern to W.A. Part of the N.T. barramundi "fleet" is shore-based (small cartop boats), as is the common practice in W.A. in the Ord and Fitzroy areas. However, some of the port-based fleet of larger N.T. boats have been attracted to fishing in W.A. during the N.T. closed season. This practice has had some bearing on the Department's consideration of a request by an Ord (Wyndham based) barramundi fisherman for a similar closed season on biological grounds (to prevent capture of ripe females).

Prior to the Seventies, professional barramundi fishermen in the Kimberleys catered almost exclusively to limited local demand in the towns of Broome, Derby and Wyndham (Morrissy 1969). By 1979 most of the catch was said to be frozen and shipped to the south for higher capital city prices. Nowadays, most of the local supply of barramundi is said to come from (illegal) netting and sale of fish by amateurs.

(iv) Amateur fishing

Apart from the obligation for an amateur angler, fishing in freshwater for barramundi, to hold an Inland Fisherman's Licence (since 1970) and to use a (rod and) line, no catch regulatory measures are in force (size and bag limits, closed season, etc.) Although there have been calls for these and other measures from the public, the Department has had to weigh their biological, or social, necessity against the extreme difficulty of enforcement.

Enforcement and public relations for the Kimberleys rest with one fisheries inspector based at Broome (primarily responsible for the pearling industry) and, since 1970, one Wildlife Officer based at Wyndham.

No survey has been carried out to establish whether fishing for barramundi in the Ord River is worthwhile, or not, for the average, especially tourist, angler. Certainly tourist anglers encountered there have been disappointed to learn that the dams do not contain barramundi. For the river downstream from Kununurra, an important issue is lack of ready access, particularly for tourists in non 4 WD vehicles (Fig. 1). There are only two easy access points, the river immediately below the Diversion Dam wall at Kununurra and the concrete river crossing (often submerged) at Ivanhoe (there parking can be congested). Other stretches of the river are difficult to locate by tracks and approach to the river bank (for boat launching) requires a 4 WD vehicle. In summary, present access to the river strongly favours residents and the more adventurous tourists and fishing pressure tends to be concentrated on a few stretches of river. The majority of tourists, including more diffident anglers, require easy, well-directed access at a greater variety of spots.

Most of the lower Ord below Ivanhoe Station, down to tidal water at Carlton Crossing and out into the broadwater of the Ord estuary, is closed to land access by the APB for Noogoora Burr Control. However, professional fishermen have been permitted by the Department, in agreement with the APB, to continue to fish (up to Carlton Crossing) using water access only. The old Wyndham road follows the west bank of the Ord closely for some distance in the vicinity of Carlton Crossing. In terms of fisheries management, this lower reach of the Ord River represents an important closed nursery ground for conservation of juvenile stocks.

(b) Cherabin (*Macrobrachium rosenbergii*)

(i) General and biology

M. rosenbergii is a large freshwater prawn widespread in the Indo-Pacific and native to northwestern Australia. It has a similar migratory lifecycle to barramundi. The stock lives and spawns in freshwater but larval development requires a salinity of about half seawater. Spawned eggs are carried into estuaries by the wet season floods; bottom crawling juveniles migrate extensive distances upstream during the latter part of the

wet season. (This life-cycle is called amphidromy*). These prawns are an important food source for predatory fish especially barramundi; see III, Fish Passes - motivation for upstream migration of barramundi.

M. rosenbergii is extensively farmed by both artisanal and modern intensive methods throughout the equatorial belt of the world and has even been introduced to temperate climates for this purpose. An up to date review can be found in Morrissy (1983) see also V,(c), Aquaculture.

(ii) Amateur fishing

M. rosenbergii is viewed elsewhere in the world as a luxury gourmet crustacean. However, it has never been exploited commercially from the north-west and is unknown on southern fish markets. Traditionally prawns are collected by hand at night from barriers, such as the Fitzroy Barrage, towards the end of the wet season. Otherwise they are fished legally using methods similar to those for marron in the southwest (dropnets, scoop nets) under an Inland Fisherman's Licence.

(c) Catfish (*Arius hexanematichthys* sp)

(i) General and biology

Northwest Australia has a rich catfish fauna in the families *Plotodidae* (eel-tailed catfish or cobbler - similar in form to the estuarine cobbler of the Swan) and *Ariidae* (fork-tailed catfish). All these catfish have pectoral and dorsal spines capable of inflicting poisonous wounds when handled. Although fork-tailed catfish are readily captured on rod and line and are fine eating, their appearance and the danger of handling them, detracts considerably from any angling attraction. The commonest catfish in north-west rivers appears to be *Arius australis* which also occurs in estuaries and coastal waters near rivers. However, in Lake Argyle, another closely related fork-tailed catfish, unnamed specifically by taxonomists as yet, has become the dominant species (presumably this species was quite rare in the Ord system prior to damming). This species has been recorded at sizes approaching 20 kg, is highly predatory, and like other ariids is of low fecundity (few, large eggs) but a buccal (mouth) incubator (ensuring high survival of juveniles). The presence of this catfish in Lake Argyle has important implications for any proposal to introduce other fish, such as juvenile barramundi, or Nile perch, to the lake; see III, Fish Passes.

* This life-cycle differs from catadromy in that the mature breeding stock lives wholly in freshwater.

(ii) Commercial fishing

Net fishing of this catfish in Lake Argyle commenced in 1978, initially to reduce predation on the planned introduction of hatchery-bred barramundi by Fish Farms International; see V,(b), Aquaculture. The catfish was found to yield large fillets of excellent quality although somewhat bland. Test marketing of fillets at the 1976 Fish Expo in Melbourne as "Argyle Silver Cobbler" gave encouraging indications of market acceptance. Fishing subsequently by local licensed professional fishermen has seen shipments of frozen fillets marketed in Perth as silver cobbler (sometimes packed by fishermen as Ord River Cobbler). The small annual catch of catfish from Lake Argyle (ca 6 tonnes, 1980-81) is a reflection of the perennial economic problem influencing all wet-fish exploitation in Australia. In 1980, the keenest fisherman was receiving $4/kg for fillets but required $4.50/kg to cover freezing and shipment costs to Perth. In June 1983, cobbler were retailing at $5.80/kg in Perth, a price considerably exceeding that for some imported seafish.

Research sampling and sampling of fishermens' catches in Lake Argyle in 1980 provided some basic catch data indicating a worthwhile fishery of impressive magnitude.

The productivity, or fish producing potential of Lake Argyle, can be predicted from a calculated morphoedaphic index of 22.8. The correlation derived for African tropical lakes between the total annual fish catch and this index, predicts a potential annual fish catch for Lake Argyle of 55 kg/ha. Taking a total area, at full supply level of 70 000 ha for Lake Argyle, the potential annual yield would be 3820 tonnes. However, it must be emphasized the African annual catch would include many fish species of a type and size not marketable as food in Australia.

(d) Other native species

The northwest has a larger diversity and more "interesting" range of freshwater fishes than the southwest, including many euryhaline species ranging between coastal and freshwaters (e.g. sawfish, rays). Many of these species, although less well-known and small compared to barramundi, are good eating and provide excellent sport fishing (e.g. the grunters). The small rainbow fish (*Melanotaenia* spp) provide excellent mosquito control and are found in the channels of the irrigation scheme. These, and other small colorful species are, or could be popularised as, suitable warm water aquarium fish. These and other species (e.g. long toms, archer fish, salt and freshwater crocodiles) unfamiliar to tourists from the south, could provide

attractive aquarium displays in a centre such as Kununurra, see V,(e), "Tourist aquaculture".

Fishing access to the lower Ord River, largely for barramundi, has been discussed under II, (a), (iv). So far as fishing from boats of cartop size is concerned, Lake Kununurra is a relatively safe venue but Lake Argyle is highly dangerous, even for larger craft in inexperienced hands. Access to the picturesque upper Ord River where it flows into Lake Argyle involves cross-country 4 WD travel across station property from the Nicholson Highway.

(c) Possible introductions of fish species

(i) Nile perch (*Lates niloticus*)

Introduction of Nile perch has been proposed by Queensland as the solution to the present absence of a large edible game fish in Queensland (east coast) water storages. As described previously, I, (a), (ii), this is only one possible solution to the "barramundi problem" of the north.

This idea was first suggested in 1968 to Queensland State fisheries, now Queensland Fisheries Service (Q.F.S.), and agreed to by the Queensland State Government. It met with a new, highly critical, policy on fish introductions when submitted in 1969 at the Commonwealth level, where ratification is required by all the States, and subsequent, at times heated, public controversy. In the early Sixties the last official introductions of exotic fish, intended for acclimatization to the wild, were two salmonids (Brook trout and Atlantic salmon from North America); these introductions, by NSW, occurred just as the conservation movement commenced to grow in Australian academic circles.

The issue of whether, or not, Nile perch will be introduced to the wild in Northern Australia is still unresolved to this date. Permission has recently (1980) been granted to Q.F.S. by the Australian Fisheries Council (A.F.C.) for a trial introduction. It is intended to hold these fish in specially constructed quarantine facilities at Walkamin in Queensland and subject them to a phased series of tests designed to reveal, or predict, any dangers likely to arise from liberation, e.g. disease, temperature tolerance allowing spread to the Murray-Darling system, etc.

The vetting of this proposed introduction has been handled by an Advisory Committee, reporting to the Standing Committee on Fisheries, formerly called the Advisory Committee on Imports of Live Food and Sport Fish and now the Advisory Committee on Endangered Species and Imports and Exports of Live Fish. W.A. Fisheries Research was co-opted to this

Advisory Committee in 1970 in an advisory role to help resolve the dilemma confronting the committee. Advice recommended the vetting procedure on a quarantined shipment of Nile perch and extensive documentation was provided. The Walkamin facility in Queensland was established by 1975 with the encouragement of the Advisory Committee which had prepared this recommendation for consideration by the 11th meeting of the Standing Committee on Fisheries in October 1975. However, a change in the organization of Queensland fisheries at that time resulted in their proposal being withdrawn. A further change in Q.F.S. led to resubmission of the proposal in 1980 and its present ratification by A.F.C. in September 1980.

In the meantime Q.F.S. had gained expertise in breeding and rearing of various native fishes (although not barramundi, as yet) at Walkamin. In the past year Q.F.S. has appointed an officer for the Nile perch project and invested considerably in further facilities for the project there.

However, an added, very recent, development is the considerable interest and expertise that has arisen in the Commonwealth Department of Health, Animal Quarantine Branch (A.Q.B.), regarding imports of live fish (largely developed over the problem posed by imported aquarium fish). The trial batch of Nile perch will have to be rigorously tested and treated for disease in Africa before shipment to Australia (to a level of "disease-free" certification acceptable to A.Q.B.). Security arrangements at Walkamin will need to be approved. Legally Q.F.S. requires a "Permit to Import" from A.Q.B.

The general controversy over the introduction of Nile perch is as follows:

Many of the large east coast rivers of Queensland contain depleted stocks of barramundi and numerous storage dams providing little recreational fishing. There has been a very strong lobbying pressure from Queensland anglers for the introduction of Nile perch. The N.T. stocks of barramundi support large, valuable commercial and amateur fisheries on undammed rivers, so that N.T. has not favoured the introduction. N.S.W. has considered the possibility of establishment of Nile perch in the Murray-Darling system with some alarm. S.A. has declared both barramundi and Nile perch as noxious fish. The Australian Assembly of Freshwater Fishermen, after hearing various views, recommended to the Commonwealth Minister for Home Affairs and Environment, in May 1982, that alternative solutions to Nile perch be more fully explored.

The view expressed by opponents is that the

introduction is not in line with latter day principles of ecological and fisheries management of inland waters. Given that Nile perch pass quarantine and biological tests, the outcome of their establishment across northern Australia in dams will inevitably lead to spread to rivers downstream from dams and to undammed rivers. In these situations Nile perch will be competing with most of the juvenile production of barramundi and the commercial coastal and estuarine fisheries for barramundi may be jeopardized - the longterm outcome is unpredictable.

Three other less expeditious alternative solutions to the "barramundi problem" have been seen since 1970 - other native fishes (none are really suitable), fish passes, see VII, and hatchery propagation of barramundi, see Aquaculture V,(b). The latter is an accepted fisheries practice (c.f. salmonids) and, together with the call for more study of barramundi, has been the most acceptable and practical alternative, in a conservation sense. However, in the early Seventies this alternative was largely theoretical with only the likelihood of medium to longterm implementation because hatchery breeding of barramundi was not a reality. Although still not accomplished in Australia, the prognosis for hatchery rearing of barramundi now appears to be short to medium term under the impetus of the Nile perch controversy, known hatchery success in Thailand, and the commercial promise of pond rearing of barramundi which requires a hatchery source of juveniles.

(ii) Ornamental fish

Possible large-scale commercial culture of aquarium fish, such as goldfish, on fish farms, is discussed under V,(d), Aquaculture.

(iii) Other species

The unauthorized spread of certain fish species to the Ord region would be highly undesirable.

Official introduction of *Gambusia* was suggested in 1977 to control mosquito larvae. The considered view of both Fisheries Research and the W.A. Museum fish taxonomist at the time was that this exotic species was a threat to small native species (as shown by experience in the south) and that small native Ord species, such as *Melanotaenia*, already provided as much control as was possible by fish. *Tilapia*, a tropical mouth breeding fish of a similar aggressive nature to *Gambusia*, is present in the southwest as a result of illegal introduction to Australia. The pattern of spread of this fish from Perth to Carnarvon has been of considerable concern to the Department, so far as its likely

further translocation (by aquarists) to the tropical waters and the Ord dams is concerned. It is very likely that this species would overrun the Ord dams. Although fished and farmed as a staple fish protein source in Third World Countries, *Tilapia* could not be marketed profitably in Australia and are small and have little angling potential.

III FISH PASSES

The earliest concern over man-made barriers to upstream migration of fish in the Ord was expressed by Sir Hudson Fysh (of the Snowy Mountains Authority) after a visit to the newly completed Ord Diversion Dam scheme in 1963 (however, he expressed concern over only the concrete ford at Ivanhoe Crossing downstream from the dam).

Knowledge of the catadromous life-cycle of barramundi was not to hand for consideration by Public Works Department, W.A., in the construction of the Diversion Dam in 1963. Advice on this characteristic of barramundi, in relation to the Ord, was made available in 1969 by Fisheries Research (Morrissy 1969). By 1969, stocks of barramundi had disappeared from the Diversion Dam and seasonal accumulations of small barramundi, and other fish, below the dam wall were readily apparent to PWD engineers and other locals at Kununurra. The attractive idea of a fish pass around the dam had occurred to PWD at Kununurra but this was likely to be a costly exercise with no basis for design, or prediction of success, from experience elsewhere.

However, in 1970 PWD and Fisheries Research agreed to fund the cost and testing of a small experimental fish lock on the Fitzroy Barrage at Camballin. The main experimental features of this lock were the provision of three openings, of variable shapes and sizes, for entry of fish, together with variation of discharge rate through the openings and supplementary flows for attraction of fish. This lock was tested in 1971 and 1973 by Fisheries Research towards the end of the wet season river flows when large accumulations of fish and prawns occurred below the barrage. Although barramundi were present (as shown by netting), and other species of fish were trapped in the lock, only one barramundi entered it.

Similar results have been obtained in Queensland more recently by monitoring an established channel fish pass on the Fitzroy River Barrage (Q) at Rockhampton; only 5 barramundi were taken in over a year of monitoring. A recent survey of fish passes located on a number of N.S.W. rivers for the passage of various native fishes, also attests to the difficulty of applying the fish pass concept to Australian rivers and fish. Most of the body of literature on the design and operation of fish passes relates to salmonids overseas.

The concept of fish passes (locks, ladders, fish ways, -) has been most highly developed for anadromous fishes, notably the Pacific salmon of western North America and eastern Asia and the

Atlantic salmon of eastern North America and Europe. The migratory life-cycle of these fish is the reverse of that of barramundi. Juvenile growth occurs in the oceans. Mature fish migrate up rivers to spawn in the headwaters. Since this migration is essential to the continuance of the species, salmonids display considerable tenacity in surmounting natural barriers in torrential, high gradient rivers by high speed swimming and jumping behaviour. Despite this behaviour and the commercial value of, as well as legal necessity for, perpetuating, these salmon runs on dammed rivers, development of fish pass design for salmonids has had a long and costly, although largely successful, history. In many cases, fish passage on dammed salmon rivers is not attempted. Artificial hatchery breeding of ripe fish trapped below dams is utilized to provide releases of juveniles back to the ocean.

The motivation for upstream migration of barramundi may be contrasted with that of salmonids. Only immature (juvenile) barramundi appear to carry out extensive upstream movement. This movement accompanies the similar movement of freshwater prawns, a favoured food, and separates the juveniles from the breeding stock of large, highly predatory, barramundi which remain in tidal or lower reaches of rivers. Most of the upstream movement of juvenile barramundi occurs during flood time when natural barriers, in meandering rivers of low gradient, are submerged. Although barramundi display jumping behaviour when hooked by anglers, this behaviour has not been seen in free fish, at barriers, over many hours of observation.

Canvassed fish biologists with wide experience of northern rivers and barramundi discount the concept of fish passes for the species. There is no evidence that a salmonid-type pass will work for a differently motivated, and perhaps easily deterred, species such as barramundi. Too, the success of a fish pass depends on the availability of fish to enter it. Considering the Ord dams, successful passage of comparatively few fish would not provide a worthwhile stocking rate for the large upstream storage dams, particularly Lake Argyle. Moreover, survival of small barramundi in these dams is likely to be severely prejudiced by the present large stocks of predatory catfish.

IV FISH DEATHS

Mass fish mortalities in the Sixties in the Ord River adjacent to, and receiving drainage from, the crop irrigation area, were considered initially as natural events. Observation of such an event by a Departmental Wildlife Officer in 1971 prompted further field investigations by Fisheries Research and laboratory analysis of fish and water samples (Government Chemical Laboratories, 1979). This work showed that the aquatic food chains of the Ord were severely contaminated by pesticides from the irrigation drainage, notably by DDT and metabolites. Levels of DDT in fish were especially high, particularly in barramundi and catfish, and the highly susceptible prawn, *Macrobrachium*, was absent. Spraying of pesticides ceased in 1974 with the discontinuation of the cotton industry. However, chlorinated hydrocarbon pesticides are extremely persistent in

aquatic ecosystems due to "storage" in sediments. The long term persistence of pesticide levels in the river is being monitored by Fisheries Research.

In a Government document, entitled "Ord River Sugar Feasibility Study - Environmental Assessment" (1976), the following related comment is recorded (p. 20) "... the probability of pesticide discharge into the Ord and Keep Rivers and the consequent damage to the marine food chains is mentioned. This damage, should it occur, will be the major adverse effect ...". Disposal of a concentrated organic effluent to the river from a sugar cane mill would pose a danger to the aquatic system because of the high biological oxygen demand of such material.

Some degree of eutrophication of any water body is inevitable when the drainage to it carries an organic and nutrient loading from an agricultural area. In a mild form, such organic pollution can be viewed as beneficial since aquatic productivity is raised; but in the extreme, resulting toxic algal blooms and associated oxygen depletion cause severe aesthetic problems and fish deaths. In this regard, the increased flow of the lower Ord River during the dry season, due to the Lake Argyle storage, is a mitigating influence. This capability for diluting agricultural drainage and flushing the river, can be viewed as an important management tool for maintaining compatibility between the river life and agriculture.

The development of aquaculture (see V) on the irrigation area is also highly vulnerable to water -, or air -, borne pesticides and perhaps water - borne herbicides used for weed control in Lake Kununurra and the irrigation supply channels. Allocation of irrigation land with any history of pesticide usage is also highly prejudicial. The need for safe-guarding aquaculture projects by a degree of isolation in land allocation is strongly indicated; the idea of an "Aquaculture Park or Reserve" may be a useful means of identifying and satisfying these requirements.

V AQUACULTURE

(a) Introduction

The modern worldwide development of aquaculture, or fish farming, has a short history of thirty years, or so, (post WW II) although the practice has ancient roots in China. Currently world aquaculture supplies about the equivalent of 10% of the world seafood harvest from conventional catch fisheries (74 million metric tonnes). Centres for modern aquaculture development and innovation have been Israel, Japan, S.E. Asia and other Third World Countries (promoted by FAO), USA, Europe and Russia. Aquaculture development in Australia largely commenced in the late Sixties. Progress in freshwater is given in Morrissy (1980), together with an outline of the variety of aquaculture practices and species.

(b) Barramundi

Following their earlier proposal to farm Cherabin (*Macrobrachium*) on the Ord Irrigation area see V, (c), below, Fish Farms International Ltd (Aquaculture International Australia Ltd), an Adelaide based company, proposed "ranching"of barramundi in Lake Argyle. The W.A. Government was consignatory to the "Fish Farming (Lake Argyle) Development Agreement Act 1976". The entrepreneurial drive for this project came from an Adelaide businessman who, upon returning in the Sixties from studies in the U.S.A. on the management economics of aquaculture, became fired with enthusiasm for the general opportunity presented by the availability of water and favourable climate for aquaculture at the Ord.

The basis for this project was to be a barramundi hatchery, situated near Wyndham for seawater access. Juvenile barramundi reared in this hatchery were to be stocked in Lake Argyle in very large numbers. Commercial harvesting of grown fish was to be accomplished by gill-netting or trapping as the fish sought to leave the lake to move down river for spawning. Part of the lake stock was to be assigned to recreational fishing. Neither a pilot scale, nor a full-scale hatchery (parts of the Agreement), eventuated on the Ord.

Despite the experience of Fish Farms International in the Argyle barramundi project, the current feeling in Australia towards eventual successful aquaculture of the species is more buoyant than in the previous decade. This feeling has been engendered by the Nile perch controversy, belated, but growing, northern biological research on barramundi and concern over the failing catch rate of barramundi from commercial fisheries, such as in the N.T., for a large Australian market for the fish, as well for resident and tourist angling. Most importantly, commercial pond rearing of barramundi to marketable size, or even for pond "fish-outs" for tourist anglers, is a likely prospect. Cage culture of barramundi in floating net pens may be a means of exploiting the waters of Lake Argyle and the Diversion Dam. Cage culture is used for aquaculture of salmonids, carp and other fish, including barramundi in Thailand.

However, any development will be dependent upon hatchery breeding of barramundi which has not been accomplished in Australia to date. Juvenile barramundi have been successfully air freighted from the Kimberleys and reared to large sizes with ease in heated seawater tanks at the W.A. Marine Research Laboratories, Perth (House 1979). A high growth rate and ready adaption to confinement and hand-feeding (on small bait fish) are encouraging characteristics for eventual intensive pond culture. However, no success has been achieved in breeding the fish in captivity when they reached mature ages. Controlled day length and water temperature cycles have not been successful even in stimulating partial gonad development, allowing final ripening to be induced using hormones. Further

research using protracted hormone injection is prevented by the small number of large fish which can be held at the laboratories (2 or 3 fish) and the difficulty of shipping fish to Perth from the north.

Reliable large scale spawning of barramundi (an extremely fecund species) has been carried out at the Songkhla hatchery in Thailand since the Sixties. This hatchery is situated on a river estuary. Ripe wild fish about to spawn are either captured from the river nearby or have been reared in adjacent ponds. Spawning either occurs naturally or can be induced using the well-known hormone technique. Sex inversion (change from male to female) has not been described by this hatchery. Reports, in English, from this hatchery are available. In 1982 an officer of the Q.F.S., responsible for breeding of native fishes at Walkamin, Queensland, visited the Songkhla hatchery for familiarization with the techniques used there.

Obviously barramundi require some factor(s) in their environment other than annual day length and water temperature cycles (solely required by many fish) to induce maturity and gonad development, as shown by negative breeding results in Perth and Adelaide. In locating a hatchery in the north, the unreliability and difficulty of capturing and shipping any large barramundi (particularly females) from the wild fishery during the wet season is well recognized and will probably necessitate holding a pond stock of breeding size fish. Location of ponds close to seawater, and preferably with a tidal exchange through the ponds, could be very difficult to achieve in the Kimberleys because of the large tidal range. For these and other reasons, such as location costs, there is a short to medium term prospectus that such a hatchery will be established first in the N.T. or Queensland. Distribution of large numbers of small fry, from such a hatchery, over northern Australia presents no technical problem (apart from cost). In the medium to long-term a large, valuable commercial trade in hatchery fry is envisaged.

(c) Cherabin (*Macrobrachium rosenbergii*)

A number of attempts have been made to farm both marine penaeid and the above freshwater prawns in Australia with no commercial success evident to date. Because of the high priced export, if not local, market for prawns, farming is widespread in many warmer climates although, as is characteristic of aquaculture investments, the past and present record is strewn with many individual failures. The basis of all modern prawn farming is large scale hatchery production of juveniles. The latter are pond-raised either extensively (low yields/unit area in very large ponds) in Third World Countries where land and labour are cheap (U.S. investments) or semi-intensively (higher yields/unit area, in small ponds in more developed countries, Japan, Hawaii, etc.). For *Macrobrachium*, a very large body of technical literature exists back to 1960 when the hatchery breeding technique was first

developed in Malaysia by FAO. Morrissy (1983) provides a recent review of the potential for *Macrobrachium* farming in northern Australia where *M. rosenbergii* is a native species, as described earlier, in II,(b).

Of the two proposals to farm *Macrobrachium* on the Ord Irrigation area, the earliest has been long abandoned and the latest has just commenced.

Fish Farms International proposed prawn farming at the Ord in the early Seventies, but this pioneering idea was not developed to a test stage.

The second (current) project was started in 1980 by local Kununurra interests, who, as a result of touring S.E. Asian fish farms in the Seventies, returned enthused with the potential of the irrigation area for *Macrobrachium* farming. Although initially they proposed to develop and manage the prawn farm alone, Fisheries Research advised that the project should obtain the services of an Asian with experience as a *Macrobrachium* farm manager. The first such person, from Malaysia, could not communicate well in English and a better suited replacement has just started work (June 1983).

The hatchery and ponds for the project are located on the Pack Saddle Plain irrigation area. Apparently two obstacles have been experienced by the project. Firstly, agreement to the siting of the farm and allocation of land took about two years. The second, and a current, problem is that although an irrigation supply channel runs close to the farm, water supply has been denied from this source and ponds are having to be filled using small pumps drawing directly from the Diversion Dam. The situation is said to be an unreasonable limitation placed on the project.

(d) Ornamental fish

The largest and most successful "aquaculture industry" in Australia is the trade in aquarium fish and related equipment. Most of this trade in freshwater fish species relies on fish produced and sold at low cost (by Australian standards) from S.E. Asia. The growth in shipments has paralleled the development of fast, direct international flights from Asia. This trade has become of increasing concern because of the opportunities presented for entry into Australia of highly undesirable exotic species and foreign diseases carried both by the fish and in the accompanying water. Because of the very large number of, often very similar, fish species involved, the difficulties of custom inspection at all international airports has been a relatively token effort, applied to an incomplete list of permitted and prohibited species. This problem has been tackled for many years under an Advisory Committee to the Standing Committee on Fisheries. Recently a "short" list of permitted species, most valued by the aquarium trade and more easily identified by customs inspection, has been implemented. A further step, soon, will be to require the

aquarium trade to set up licensed quarantine facilities at all ports of entry. An important effect of this control will be a rise in the cost of imported aquarium fish which should certainly provide more viability for the domestic aquarium fish farming (breeding) industry. In fact, the desirability of breeding aquarium fish in Australia to supplant imports, and the risks involved, has previously been put forward. However, this proved unpopular with the aquarium trade on obvious economic grounds.

Most of the trade in freshwater aquarium fish is in the goldfish, *Carassius auratus*. One large commercial goldfish farm has operated profitably in Victoria for a number of years. In the colder climate of southern Australia goldfish have a restricted annual breeding season.

All these aspects suggest that breeding aquarium fish in the Ord region for sale in southern Australia is, or could be soon, a very attractive proposition. Some consideration should be given to promotion of the region for investment in such fish farming, particularly in the present S.E. Asian centres of production.

(e) "Tourist aquaculture"; fish display aquariums and fish-out ponds

Short term opportunity exists at a centre such as Kununurra for successful development of self-supporting "tourist aquaculture". A well-presented aquarium display of aquatic life is a public drawcard especially for tourists as entertainment and a source of information. At present most tourists would leave the region not having seen a live barramundi, Cherabin, etc. and not having had any opportunity to learn about the fascinating life cycles of these famous native species. Such a centre would also be an important centre for dissemination of public relations material for the Department of Fisheries and Wildlife, sorely needed because of staffing problems in the Northwest. Opportunities for fish farming, descriptions of aquaculture facilities and techniques could be promoted too, to attract visiting potential investors.

Many centres, elsewhere in Australia and the world, feature a giant replica of a prominent local product. For example, pineapples and bananas in Queensland, Rainbow trout at Adaminaby near Lake Eucumbene, N.S.W., and the yabby at "Yabby City", Clayton, S.A. Blatant entrepreneurism such as proclaiming Kununurra, "The Barramundi Capital of the Kimberleys", may be suggested from parallels elsewhere.

Additional displays, in such a centre, of crocodiles (farming is currently practised near Darwin), the birds of the region (finches, etc. are of commercial importance) and other wildlife, are of obvious interest.

An important expansion of this centre could be the eventual provision of barramundi fish-out ponds when hatchery-bred juvenile fish become available. This type of fishing would

be a novel attraction to the majority of tourists (of limited or no angling experience). Certainly commercial fish-out ponds are viable and popular operations for trout in many places in temperate regions.

VI SUMMARY

(a) Barramundi (*Lates calcarifer*) and Cherabin (*Macrobrachium rosenbergii*) are two extremely valuable aquatic species, native to the Ord.

(i) Barramundi support a small commercial fishery in tidal waters. The species is Australia's most popular and renowned northern sport fish, especially as a tourist attraction, and it has considerable potential for commercial aquaculture development.

The most favoured avenue for short to medium term enhancement of stocks of this fish is through hatchery production of juveniles, rather than provision of fish passes or substitution by Nile perch.

For technical and contemporary reasons a hatchery for breeding Australian barramundi is likely to be established first in Queensland. Hatchery fry for the Ord may be obtainable from this hatchery, but, probably only in limited numbers, provided the stock is free of disease. Consideration of the cost of air transport, demand exceeding supply on the east coast and eastern states policy on distribution, indicates the medium to long term desirability of establishing a hatchery on the Ord. Such a hatchery would have also the virtue of providing a considerable tourist attraction.

(ii) Cherabin are one of the most highly exploited and valuable species in the world pool of species suitable for aquaculture. Northern Australia is exceptional amongst tropical equatorial regions in largely neglecting this potential so far, more so in having native stocks as a basis for development. The Ord region is climatically most favourable for cherabin growth. The developed irrigation scheme, of abundant water supply and flat land, is highly suitable for pond culture development. The technology for hatchery and pond culture of cherabin is well developed overseas but, of course, lack of experience in management skills amongst Australians is a serious limitation.

(b) Aquaculture

Development has been limited in Australia because of the absence of artisanal skills and incentive for food production. Because of the high failure rate of, usually

much publicized, ventures, both in Australia and overseas, aquaculture tends to be viewed with some justifiable scepticism in bureaucratic circles. Aquaculture is highly dependent upon the individual skills of particular entrepreneurs (more so than agriculture) and considerable discretion is required when encouragement is sought from government for particular proposed ventures. Aquaculture is a highly attractive concept and many proposals are ill-founded, requiring discerning advice at the outset, both in the public and private interest.

In regard to the discontinued projects for cherabin and barramundi on the Ord, both were well-founded in concept although there were considerable reservations concerning technical feasibility at the time and in this pioneering field. Their most positive aspect was recognition of the potential offered by the Ord development for aquaculture.

The short to medium term potential of the Ord for an ornamental fish culture industry is indicated. Encouraging factors are an economic incentive because of restrictions being placed on fish importation, climate and proximity to Asian markets. Evaluation of this potential by present Asian producers, possibly interested in Australian investment, would be useful.

Considerable short term potential exists at Kununurra for development of "tourist aquaculture". Initially this venture would take the form of aquarium displays of the notable fish species (easily obtained from the wild) and related life-history, etc. information; local features which would be much appreciated by tourists. In the longer term this facility could be expanded to provide, for example, barramundi "fish-out" ponds for tourists.

(c) Unfortunately, the present fish stocks of the Ord River below the Diversion Dam are highly vulnerable to chemical and organic pollution from the adjacent agricultural area. However, the capability for providing dry season flow of the river from the Lake Argyle storage is an important management tool in this regard.

A requirement for safe-guarding aquacultural projects from chemical pollution needs to be satisfied in land allocation and water supply.

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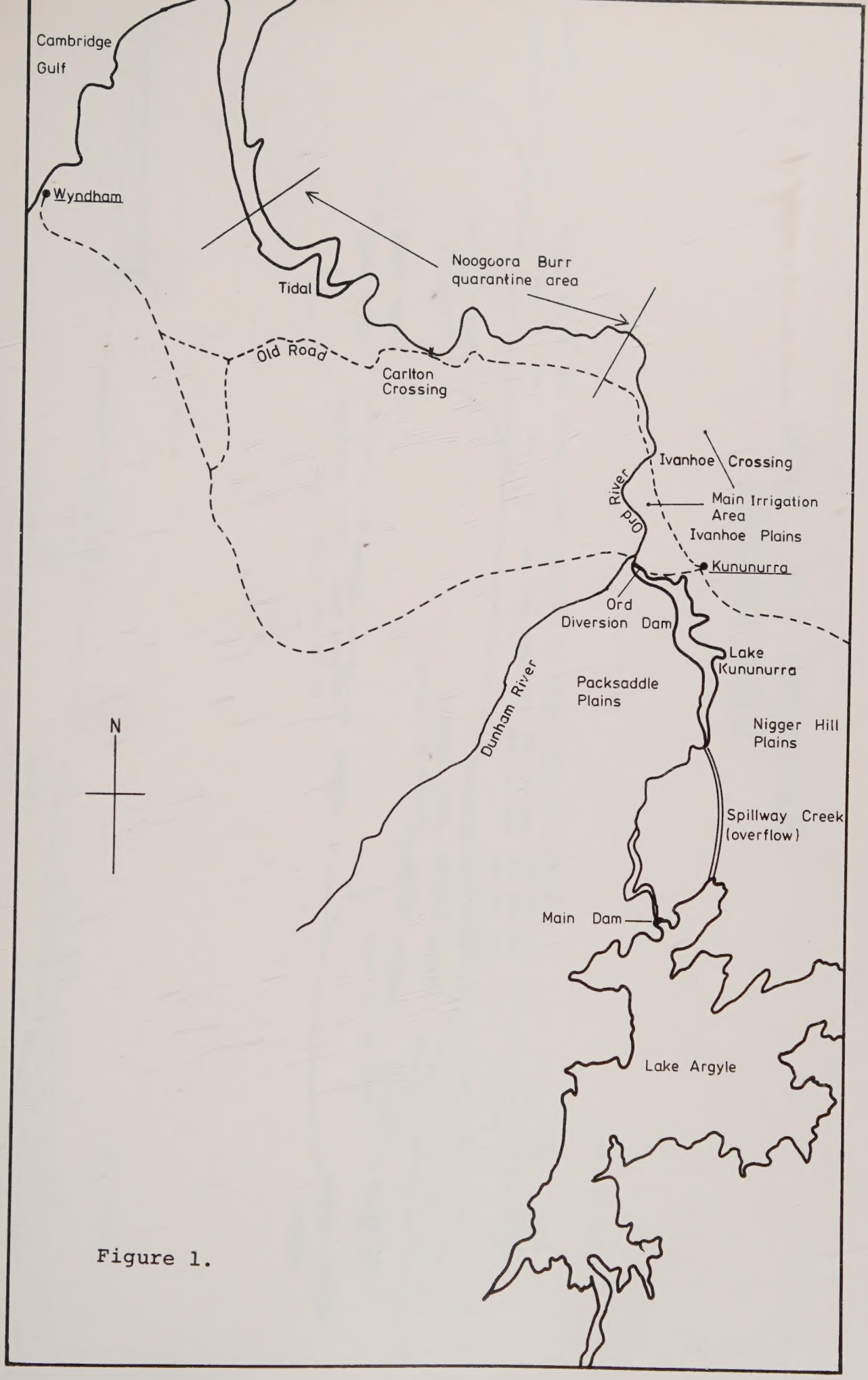
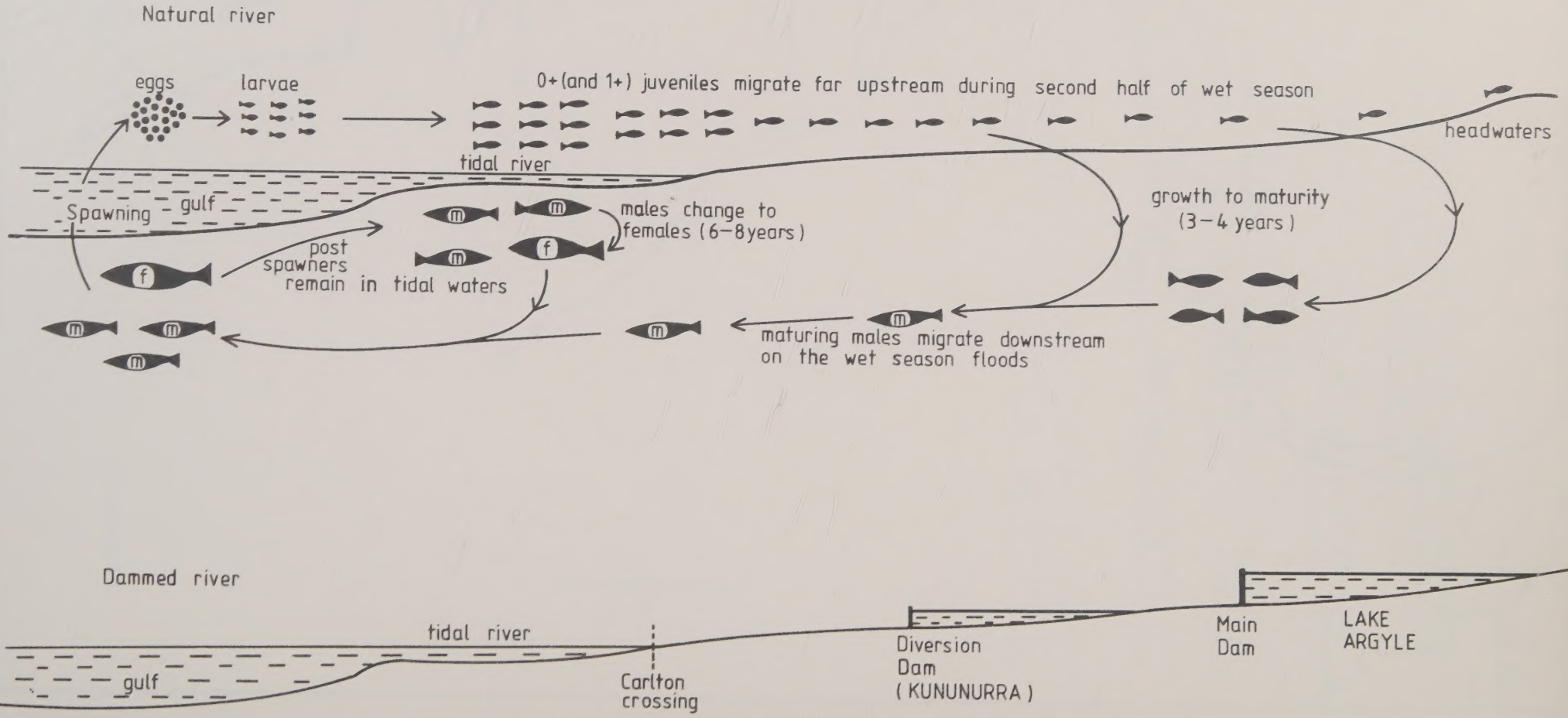

Cambridge
Gulf
Wyndham
Tidal
Noogoora Burr
quarantine area
Old Road
Carlton
Crossing
Ivanhoe Crossing
Ord River
Main Irrigation
Area
Ivanhoe Plains
Kununurra
Ord
Diversion Dam
Lake
Kununurra
Packsaddle
Plains
Dunham River
Nigger Hill
Plains
N
Spillway Creek
(overflow)
Main Dam
Lake Argyle

Figure 1.

Figure 2.

Barramundi Life Cycle
(Lates calcarifer)



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